Calcium, magnesium and phosphorus status of elderly inpatients: dietary intake, metabolic balance studies and biochemical status

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The calcium, magnesium and phosphorus status of a group of elderly inpatients was studied by use of duplicate meal analysis over a 5 d period and biochemical indices in twenty-one patients, and metabolic balance (5 d) in six of these. Mean daily Ca intake was lower than that of apparently healthy elderly subjects in metabolic equilibrium, although commensurate with present UK recommendations. Metabolic balance was negative for Ca. Mean daily Mg intake was approximately half the US recommendation, and half the intake at which metabolic balance has been observed in healthy elderly people. The five patients studied were in metabolic balance for Mg. Mean daily P intake was close to the UK recommendation, but negative metabolic balance was observed. The disparity between official recommendations for Ca intake, factors contributing to suboptimal Ca status, and measures that may improve Ca status in this group are discussed.

Calcium: Magnesium: Phosphorus: Old age.

Over the next decade in the UK there will be a 45% increase in the frailest section of the elderly population, those aged 85 years and over (Office of Population Censuses and Surveys, 1985). In 1984 over one-third of all general medical and surgical beds, and over one-quarter of orthopaedic beds were occupied by elderly patients (Department of Health and Social Security, 1986). Old age, intercurrent illness and hospital admission may threaten the nutritional adequacy of dietary intake, and the elderly should probably be considered as a separate group with regard to recommendations for nutrient intake (Schneider *et al.* 1986).

The optimal level of calcium intake in the elderly is disputed, and its relative importance in the aetiology of osteoporosis, whether in the achievement of peak adult bone mass or the decline to critical levels in old age, is unknown. There are few studies of magnesium status in the elderly, despite the existence of a number of factors which might lead to deficiency. Little is known of the importance of differing levels of phosphorus in the diet, much of the published work relating to inter-relations with other elements.

In an earlier study of the nutrient content of hospital meals we found that the amounts of Ca and P in the food and drink offered to elderly people contained more Ca and less Mg than current recommendations (Thomas *et al.* 1986). We now report values for actual intake measured by duplicate meal analysis in twenty-one elderly long-stay patients, together with metabolic balance information on six of this number. Our findings are discussed with regard to improving the nutritional status of these elements in this group of old people.

PATIENTS AND METHODS

Twenty-one inpatients of a geriatric long-stay and rehabilitation unit (seventeen women and four men) mean age 81·7 (range 63–89) years, were studied. None of the patients smoked, eighteen were edentulous and eleven reported problems with ill-fitting dentures that

Table 1. *Details of the patients (all female) who underwent metabolic-balance studies*

Age (years)	Body-wt (kg)	Diagnosis	Drug therapy	Mobility	Outcome at 1 year after balance study
85	50·6	Osteoarthritis, recurrent urinary infections, chronic leg ulcers	Prochlorperazine, fenbufen, chlormethiazole	Walking < 10 yards with Zimmer frame	Stable
72	57·0	Ischaemic heart disease, chronic leg ulcers, sacral pressure sores, depression	Mianserin, amitryptiline, baclofen	Walking < 10 yards with Zimmer frame	Improved, awaiting place in rest home
65	63·5	L. hemiplegia, epilepsy	Phenytoin, phenobarbitone, dipyridamole, baclofen, paracetamol	Wheelchair independent but needs help transferring from bed to chair, chair to toilet	Died
78	73·0	Ischaemic heart disease, post-bereavement depression, L. hemiplegia	Naftidrofuryl, paracetamol, glyceryl trinitrin	Walking with gutter frame limited independence	Died
80	40·3	Parkinson's disease, hypothyroidism	Thyroxine, levodopa + carbidopa, orphenadrine, chlormethiazole	Limited mobility with two aides and Zimmer frame	Improved, walking with frame and one aide
81	53·1	Peripheral vascular disease, leg ulcers	Chlormethiazole	Walking < 10 yards with Zimmer frame and one aide	Stable

affected their eating habits. Metabolic balance studies (5 d) were performed on a subgroup of six patients in whom such a complicated investigation was possible. These six patients all had a regular bowel habit, and other details are given in Table 1. All patients had been resident on the ward, were in a stable medical condition, and had been consuming the hospital diet for more than 3 months. Patients were excluded from the study if they had gastrointestinal, hepatic or renal disease, or if they had received vitamin or mineral supplements at any time in the previous 6 months. Most were receiving some form of medication, but none were taking steroids, isoniazid, aluminium-containing antacids, tetracyclin, anticonvulsants or thyroxine. One patient was taking a thiazide diuretic and one a loop diuretic, but neither was a subject for a metabolic balance. Note was taken of the season during which observations were made, April–September being classed as summer and October–March as winter. The history of a fracture of the hip, wrist or verebra in the preceding 5 years was noted.

Diet collection and metabolic balances

All sample collections were undertaken by staff familiar to the patients, with minimal interruption of dietary habits and ward routine. Collection of diet included all hospital meals, medicines, drinks, snacks, sweets, and any food brought by visitors. Every item of oral intake was exactly duplicated by careful weighing as previously described (Bunker *et al.* 1984; Thomas *et al.* 1988). Metabolic balances were conducted over a 5 d period, with intake samples collected as described previously, but otherwise as described in a previous paper (Bunker *et al.* 1984). Carmine was used as a marker for the faceal collection period.

Analyses

Analysis of the total diet offered to the patient, rejected food and liquids, faeces and urine was performed as described by Bunker & Clayton (1989). All analyses were performed in triplicate. Precision and recovery experiments were performed to ensure analytical quality, and National Bureau of Standards (NBS) bovine liver was used as a reference material (NBS reference no. 1577a).

Blood collection

Venous blood was collected from nineteen patients at 09.00 hours with minimum stasis into heparinized tubes, and plasma Ca, P, Mg, total protein, albumin levels and activity of plasma alkaline phosphatase (*EC* 3.1.3.1) were determined (for methods, see Bunker & Clayton, 1989).

Ethical considerations

The present study was approved by the Joint Ethical Subcommittee of the Southampton and South West Hampshire Health Authority and the Faculty of Medicine of the University of Southampton.

Statistical analysis

Values were assessed for normality of distribution. Means, 95% confidence intervals, correlation coefficients, unpaired t tests, multiple and stepwise regressions were calculated using a Minitab package (Minitab Incorporated, 1985) on an IBM 3090/150 mainframe computer. A probability value of $P < 0{\cdot}05$ was accepted as significant.

RESULTS

Results for men and women were similar, and have been considered as one group for the purposes of statistical analysis. The mean daily intakes for all twenty-one patients are given in Table 2, which includes values for a group of healthy elderly people living independent

Table 2. *Nutrient intake determined by duplicate meal analysis over a 5 d period in twenty-one geriatric inpatients**

Nutrient	Geriatric inpatients: Mean intake	Geriatric inpatients: 95% Confidence interval	Mean intake of apparently healthy elderly†	Recommended intakes
Calcium				
mmol/d	19·8	17·5–22·2	25·1	12·5‡ (20)§
mmol/kg body-wt per d	0·33	0·28–0·38	0·38	
mmol/10 MJ per d	38·8	35·2–42·4	31·9	
Phosphorus				
mmol/d	27·4	23·9–30·9	41·6	25·8§
mmol/kg body-wt per d	0·48	0·39–0·56	0·63	
mmol/10 MJ per d	53·1	47·7–58·5	52·8	
Magnesium				
mmol/d	5·8	5·0–6·5	10·7	♂ 14·4§
mmol/kg body-wt per d	0·10	0·08–0·12	0·16	♀12·3§
mmol/10 MJ per d	11·4	10·3–12·4	14·0	

* For details of subjects, see Table 1 and for details of procedures, see p. 213.
† Bunker & Clayton (1989).
‡ Department of Health and Social Security (1979) recommended daily intake of Ca for those aged > 75 years.
§ (US) National Academy of Science (1980) recommended daily dietary allowance for P and Mg for those aged > 51 years.

Table 3. *Results of metabolic balances for calcium, phosphorus and magnesium in six long-stay elderly inpatients**

	Ca (mmol/d)		P (mmol/d)		Mg (mmol/d)	
	Mean	95% Confidence interval	Mean	95% Confidence interval	Mean	95% Confidence interval
Total intake	20·1	11·8–28·6	29·3	24·9–33·6	5·8	4·3–7·2
Total excretion	24·0	14·7–33·7	31·5	27·1–35·9	6·0	5·8–6·2
Faecal excretion	22·0	13·1–30·9	18·9	14·2–23·7	4·6	2·6–6·6
Urinary excretion	2·2	0·8–3·6	12·5	11·4–13·6	1·5	0·8–2·1
Apparent absorption	−1·7	−6·4–3·0	10·3	8·5–12·2	1·2	0·5–1·9
Net retention	−4·0	−7·8 to −0·2	−2·2	−3·7 to −0·8	−0·2	−1·1–0·6

* For details of subjects, see p. 211 and for details of procedures, see p. 213.

lives in the community and clinically well, for comparison (Bunker & Clayton, 1989). The mean molar Ca:P ratio of the diet was 1:1·32 (equivalent to a mass ratio of 1:1·02). Results for energy and protein intake have been presented elsewhere (Thomas *et al.* 1988). Ten of the twenty-one patients gave a history of recent fracture, and fourteen patients were studied in the winter months and seven in the summer.

Results of the six metabolic balance studies are given in Table 3. Apparent absorption is defined as actual intake minus faecal excretion, and net retention (or balance) as intake minus total excretion. Only in the case of Mg balances did the 95% confidence interval encompass zero.

Table 4. *Plasma levels for twenty-one geriatric inpatients**

	Long-stay geriatric inpatients		Apparently healthy elderly†‡	Laboratory reference range for healthy young individuals in this laboratory
	Mean	95% Confidence interval	Mean	
Calcium (mmol/l)	2·30	2·23–2·36	2·32[1]	2·15–2·55
Phosphorus (mmol/l)	1·01	0·94–1·08	0·90[1]	0·70–1·50
Magnesium (mmol/l)	0·80	0·72–0·87	0·87[1]	0·75–1·50
Total protein (g/l)	74·5	71·8–77·2	73·0[2]	63–80
Albumin (g/l)	34·9	32·8–37·0	45·0	32–50
Alkaline phosphatase (*EC* 3.1.3.1) (IU/l)	264	213–314	194[2]	100–300§

* For details of subjects, see p. 211.
† Bunker & Clayton (1989).
‡ Bunker *et al.* (1984).
§ Using the same method and substrate as in Bunker *et al.* (1984).

Plasma levels of Ca, P and Mg (see Table 4) did not correlate with intakes of these elements (either as daily intake, intake per kg body-weight, or intake per 10 MJ energy in the diet). There was a significant correlation, unaffected by body-weight, between daily energy intake and that of Ca ($P = 0{\cdot}002$), P ($P = 0{\cdot}001$) and Mg ($P = 0{\cdot}003$). Daily protein intake showed a significant correlation with that of Ca ($P = 0{\cdot}03$), P ($P = 0{\cdot}01$) and Mg ($P < 0{\cdot}001$) and was unaffected by body-weight. There was a significant correlation between daily intakes of Ca and P ($P < 0{\cdot}001$), Ca and Mg ($P = 0{\cdot}02$), and P and Mg ($P < 0{\cdot}001$). Stepwise multiple regression was performed with a model which included age, sex, body-weight, daily energy intake, daily protein intake, season, and history of recent fracture. Both protein intake and season were significant influences on the intake of Ca and P ($P = 0{\cdot}05$). Intake was higher in the winter months, but there appeared to be no seasonal difference in the Ca or P density of the diet. Protein intake was the only statistically significant influence on daily Mg intake. Using a similar stepwise regression model including energy, Ca, protein and P intakes, only Ca had a statistically significant association with a history of fracture in the previous 5 years ($P < 0{\cdot}05$). The mean intake of Ca was lower in those patients with a history of fracture ($P < 0{\cdot}05$). At the time of the present study serum alkaline phosphatase activities were similar in patients with and without a history of fracture.

DISCUSSION

The present study appears to be the only one in which duplicate meal analysis and metabolic balance techniques have been used to assess the nutrient status of elderly inpatients, and compare the findings with a control group studied in the same manner. The use of such techniques requires continuous and careful supervision, and is a complex task in any age-group, but especially so in these dependent elderly patients.

The mean daily intake of Ca in long-stay elderly patients (19·8 mmol for the whole group and 20·1 mmol for the six balance-study patients) is comparable with that obtained by dietary questionnaire or weighed record in other UK studies of hospitalized elderly subjects (varying from 19·0 to 21·9 mmol/d) (Evans & Stock, 1971; MacLellan *et al.* 1975; Vir & Love, 1979), though the latter methods probably underestimate actual intake (Nelson *et al.* 1988).

There is a conflict of learned opinion on Ca requirements. In the USA the recommended safe level of daily intake for Ca has been halved from 25 mmol (National Research Council, 1948) to 12·5 mmol (Food and Agriculture Organization/World Health Organization, 1962), and then increased to 20 mmol (National Academy of Sciences, 1980). The current UK recommended daily amount of 12·5 mmol (Department of Health and Social Security, 1979) was established after the Food and Agriculture Organization/World Health Organization (1962) report and has remained unchanged. Both USA and UK recommendations take age and sex into account only up to the age of 18 years. The recommendations are largely based on work in young individuals, and Ca requirements may increase significantly around the menopause (Heaney *et al.* 1978) even to levels of 37 mmol/d. (Heaney *et al.* 1977). Other relevant age-related changes suggest that the elderly be treated as a special group: reduction in Ca absorption (Bullamore *et al.* 1970), inability to adapt to low intake (Ireland & Fordtran, 1973), decreased intake and production of vitamin D (Slovik *et al.* 1981; MacLaughlin & Holick, 1985), declining osteoblastic function (Parfitt *et al.* 1983), vitamin D-resistant Ca malabsorption (Francis *et al.* 1984), and the role of androgens in Ca absorption and the maintenance of bone mass (Nordin *et al.* 1985; Devogelaer *et al.* 1987).

The elderly patients reported here were in negative metabolic balance on a mean daily Ca intake (20·1 mmol), well below that at which equilibrium has been observed in apparently healthy elderly people (25·1 mmol), whereas housebound subjects were in negative balance with a mean daily intake of 20·0 mmol (Bunker & Clayton, 1989), comparable with our smaller number of hospital patients studied by the same methods. The housebound and hospitalized subjects were similar in terms of physical disability and illness, the main distinguishing feature being the availability of family and social support services in the former group. Body surface losses of Ca, P and Mg were not measured in either of the studies, but can probably be disregarded (Lentner, 1981). Whether the similar negative balances of Ca observed in the hospitalized and housebound elderly reflect a decrease in apparent absorption due to vitamin D deficiency or resistance, immobility or a failure of adaptation to low intake is unclear.

Plasma levels of Ca, P and Mg of the patients in the present study were comparable with those of housebound and healthy elderly people (V. W. Bunker, unpublished observations). The observed low serum albumin levels were anticipated in this chronically ill population. Alkaline phosphatase levels were higher in the hospital group compared with healthy elderly people, though only four were greater than 390 IU/l. None of the patients displayed clinical evidence of metabolic bone disease, but the possibility of subclinical disease must be considered in this high-risk group. The observed association between lower Ca intake and history of recent fracture is intriguing and worthy of further study. If the lower Ca intake merely reflected a nutritionally disadvantaged group (because of frailty or intercurrent illness) a similar association between lower intakes of other nutrients would have been expected, but this was not the case.

The Ca density of the hospital diet compares favourably with that of the diet of the elderly at home, nutrient densities in the three groups being (mmol/10 MJ): hospitalized 38·8, housebound 36·1, apparently healthy elderly 31·9 (present study; Bunker & Clayton, 1989). This may reflect the expressed preference of the elderly for easily masticated food based on dairy produce (Thomas *et al.* 1988). Raw bran is added to food in this hospital kitchen, and might reduce absorption of Ca, P and Mg (Sandstead *et al.* 1979). The effect of high-protein diets or caffeine on the urinary excretion of Ca (Licata *et al.* 1977; Spencer *et al.* 1978; Heaney & Recker, 1982; Mahalko *et al.* 1983) is of doubtful importance in the context of the diet consumed by these subjects (mean daily protein intake being 45 g; Thomas *et al.* 1988).

The mean daily P intake of the hospital patients reported here (27·4 mmol in all twenty-one patients and 29·3 mmol in balance-study patients) is similar to that reported in housebound elderly people (Bunker & Clayton, 1989), and both groups were in negative balance, though exceeding the USA recommended daily dietary allowance of 25·8 mmol (National Academy of Sciences, 1980). Although a wide range of P intakes is compatible with metabolic equilibrium some would consider the present recommendation too high (Marshall *et al.* 1976), though negative metabolic balance has been reported in young adults consuming self-selected diets despite a high P intake (Lakshmanan *et al.* 1984*a*), and a wide variation in Ca:P ratio does not seem adversely to affect absorption and Ca status (Spencer *et al.* 1984).

Mean daily Mg intake (5·8 mmol for all twenty-one subjects and for the six metabolic balance patients) was low compared with Bunker & Clayton's (1989) housebound (8·1 mmol) and healthy elderly (10·7 mmol), yet metabolic equilibrium was observed in all three groups, with similar levels of urinary excretion. The intakes of Ca, fibre, P and protein may be of increasing importance with increasing age in women in relation to Mg balance (Lakshmanan *et al.* 1984*b*). The risk of Mg deficiency in the elderly (Thomas, 1984) is increased by lower dietary intakes, the use of diuretics, and the coexistence of other electrolyte deficiencies potentiating the development of cardiac arrhythmias. Balance studies of a larger group of elderly patients studied over a longer period might elucidate the significance of the low Mg intake observed in these patients.

Measures that would improve Ca status in this group include improving vitamin D status and increasing dietary Ca intake. Dairy foods would be a palatable alternative to inorganic Ca supplements, and the additional energy value might also be beneficial in view of a low mean energy intake observed in this group, which was only marginally higher than the expected basal metabolic rate (Thomas *et al.* 1988). The hospital practice of adding raw bran to the diet may not be wholly beneficial (Sandstead *et al.* 1979). Encouraging the consumption of vitamin D-rich foods, such as margarine and fatty fish, would improve absorption of Ca and Mg. If exposure to sunlight is inadequate, vitamin D supplements should be given (Department of Health and Social Security, 1979).

The evidence that dietary Ca deficiency is an important aetiological factor in osteoporosis is largely circumstantial. Adequate intake earlier in life may help attain optimal peak adult bone mass (Matkovic *et al.* 1979), but the use of dietary Ca supplements (whether inorganic or of food origin) in the management of osteoporosis (Lee *et al.* 1981; Albanese, 1983; Horowitz *et al.* 1984; Recker & Heaney, 1985) has yielded inconclusive results. However, a recent consensus of international opinion regarding the prophylaxis and treatment of osteoporosis (Panel of the European Foundation for Osteoporosis and Bone Disease, 1987) recommended 'a daily Ca intake of 800 mg (19·9 mmol) for Europoid women', and also stated that 'In postmenopausal women with established osteoporosis and women recognised to be at high risk of fracture, it seems prudent to recommend a calcium intake of about 1500 mg (37·5 mmol) a day'.

An expert panel of the Committee of Medical Aspects on Food (Anon., 1987) are currently reviewing the UK recommended daily amounts. Attempts to improve the validity of dietary recommendations for this age-group must develop in concert with other intiatives in the prevention and treatment of osteoporosis. Physical exercise, for example, as well as avoiding immobility, may inhibit vertebral bone loss (Krolner *et al.* 1983), increase energy intake and improve the intake of other nutrients.

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